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The Perception of Autonomous Vehicles by the Modern Society: A Survey

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Abstract: Autonomous vehicles (AV) are undergoing rapid worldwide development. They will only become a success if they are accepted by their users. Therefore, there is a need for user acceptance for these vehicles. Previous studies on acceptance of AV have identified several predictors. Inspired by these studies, our investigation is aimed at sociodemographic characteristics, including broader individual and societal acceptance, beyond technical issues to get a clear view of user acceptance. In this study, we surveyed 229 respondents, using a 46-item online questionnaire. Overall, our analysis revealed that the respondents are most concerned about crashing/malfunctioning, purchase price, liability for incidents, interaction with non-AV, performance in unexpected situations, hacking and safety. The results also revealed that the AV are perceived as "somewhat low risk" to drive. Gender, age, education level and employment status had varied relationships with the perceived concerns and general attitude towards the AV. For instance, respondents with a university degree (Bachelor/Master/PhD) are less concerned about the liability of accidents and AV system failure than those without it. Similarly, respondents between 36 – 65 years of age are more concerned and even refused to drive AV in comparison to the age ranges of 18 – 35 years and 65+ years.

1 Introduction

For centuries, the field of autonomy in vehicles has been an intriguing area of research. In the late 1400s, Leonardo da Vinci sketched a hypothetical self-propelled cart and then in the 1930s, mechanical autopilot for aeroplanes emerged. Finally, the concepts of autonomous vehicles (AV) were being produced from the early 20th century. However, these concepts used wireless and circuit-based systems, allowing for manoeuvring of vehicles using circuits embedded in roadways to pull cars along using electromagnetic fields [1]. This approach was replaced by vision-based approaches such as that of Mercedes-Benz in the 80s and 90s, who developed a vision-based system to create a long-distance autonomous vehicle that could drive at speeds of up to 80km/h on a variety of roadways [2]. Modern vehicles now have Advanced Driver Assistance Systems (ADAS) which work at several levels of autonomy, with these levels being outlined by the National Highway Traffic Safety Administration (NHTSA). The levels range from 0, no-automation, to 5, full self-driving automation [3]. An example of an ADAS is a parking system, proposed by Krasner & Katz [4], that uses sensors to find the best way to maneuver a car into a parking space without driver input. Systems such as these are being used in modern semi-autonomous vehicles as driver aids to hand over work from the driver to the car's systems [5]. As technology progresses, there will be a more and more handover of control from the driver to the vehicle, level 4 of automation being the fully-autonomous state that is a prominent talking point in the automotive industry. The level 5 AV will be able to self-drive anywhere ("full automation"), i.e. no cockpits, drivers are not required to be fit to drive and even they do not require a driving license (every person in a vehicle is a passenger).

With regards to the perception of AV in the public domain, members of the public have varying levels of understanding of the definition of autonomy in vehicles, with the level of education and previous exposure to autonomous features in vehicles having been shown to impact this [6]. This paper will assess a subset of the public's understanding of autonomous vehicle technology, as well as the likelihood that this technology will impact the vehicular industry through several factors including reducing the number and severity of car crashes, altering insurance pricing and creating new jobs. Previous surveys will be reviewed and the results of this up to date survey will be compared to those from several years ago, to gauge any shifts in public opinion over the time that autonomous vehicle features have developed and become more prominent in modern society.

The information presented in this article aims to collate findings from surveying a variety of people about their opinions of autonomous or "driverless" cars and the potential issues and benefits of using them. The proposed study involves respondents across many countries and distributed through social media and car manufacturer's industry links, to gain public opinions from multiple different cultures. The remainder of this paper will cover several topics including the aims and objectives of the study, a review of past surveys and other relevant literature related to the public perception of AV, the methodology behind creating the questionnaire and finally a discussion of the results collated from the questionnaire.

This survey uses the questions below as a set of guidelines for what information will be gleaned from the respondents:

- What are the consumers' main concerns with AV?
- How willing are consumers to use autonomous vehicle features in their cars?
- How does age affect opinions on AV?
- In what way does the highest level of education of a consumer effect opinions on AV?
- What is the current knowledge-base of consumers with regards to AV?
- What are the general opinions of consumers on the potential improvements AV can bring over traditional vehicles?

2 Aims and objectives

The aim of this study is to review the public's current perception of AV and the development of the acceptance of AV in modern society. This addresses the following objectives:

1. Review previous surveys on the acceptance of autonomous vehicles by the public.
2. Identify the public's main concerns about the impact of autonomous vehicles from previous surveys.

3. Construct a questionnaire based on previously identified key topics in the public's perception of autonomous vehicles.
4. Analyze the potential shift in public opinion of autonomous vehicles over time.
5. Form a consensus on the public's current opinion of the role of autonomous vehicles in modern society.

3 Related work

This section focuses to analyze previous surveys on the public perception of AV, to gain insight into the development of autonomous vehicles alongside any shifts in public acceptance over recent years. As stated by Thomopoulos and Givoni [7], driverless or autonomous cars are modelling the future of personal transport solutions throughout the developed world; however, there are contrasting views on the place of autonomous vehicles within modern society as well as the potential applications and the issues of the technology [8, 9]. The results of previous surveys will be the focus of this study, with these past results being a focal point of comparison for analyzing the results from the survey conducted as part of this study.

Several surveys have been conducted in the past few years to review the public's opinion and acceptance of AV [6, 10–15] as well as other pieces of work detailing potential benefits and issues with the increasing use of autonomous vehicle technology in the commercial space [9]. Several notable points are raised by these pieces of research, such as the preferred implementation of autonomous vehicle features, as well as the concerns of the public with the effect of autonomous vehicles on modern roads. This study aims to iterate upon these works and creates an up to date review of the current public perception of autonomous vehicle technology.

AV have risen in prominence in the media in the last few years, and as such more recent surveys of the public's perception of autonomous vehicles obtain different results to those of several years ago [6, 10–15]. Several companies in both the US and Europe have trialled AV on public streets, with the US having performed this some years ago with several teams participating in the DARPA urban challenge to get an autonomous vehicle to traverse an old military base with a variety of obstacles [16–18]. Companies such as Jaguar-Land Rover, based in the UK, have undertaken road testing of autonomous vehicles within the past two-three years now as part of the Autodrive project [19]. However, AV are not limited to purely self-driving cars, as modern commercial vehicles already have autonomous features available such as the ability to park by themselves, as well as having auto-steering and slowing down appropriately on motorways to match the speed of the vehicle in front of them [20].

There are contrasting opinions of the impact of autonomous vehicles on society, and these opinions often been skewed depending on the society that one lives in. Past surveys have shown variance in respondent's thoughts depending on their country of origin [15]. A notable factor to consider when reviewing this aspect of the public's opinion is that, based on where the respondent lives, there are differing levels of autonomous vehicle research. For instance, in America, there have been projects undertaken by companies such as Google [17] to put a fully autonomous vehicle on the road that does not require driver control; however, it is only in recent years in the UK that there has been a rise in prominence of trials of autonomous vehicles on public roads [19].

Previous studies [6, 10, 11, 13–15, 21, 22] using questionnaires have found several predictors of acceptance of AV. For example, it has shown that men are more likely to have positive attitudes towards AV [10], are less concerned about AV and willing to pay more [14], are more comfortable for vehicles to perform all functions [11], are less anxious with AV [13], and are more inclined to use AV than women [21]. There is a mixed response to the effect of age on AV acceptance [12]. It is reported that younger people are more inclined towards accepting AV than older people [15, 22, 23]. However, Rödel et al. [24] in their online survey found that respondents between 36 – 65 years of age have a more positive attitude and a stronger intention to use AV than people between 18 – 35 years [24]. Similarly, Nordhoff et al. [25] in their study found that older people are more likely to use AV and are more positive towards vehicle functionality, but they doubt on the effectiveness of the vehicle compared to their existing travel mode.

On the other hand, existing studies have also looked into the socioeconomic aspect of the respondents as a predictor of user acceptance. For example, it has been found that people with higher income are willing to pay more for vehicles fitted with advanced automated driving features [14, 22]. It is also reported that people with higher annual mileage are more inclined towards AV [14, 26] and are willing to pay for high automation levels [22].

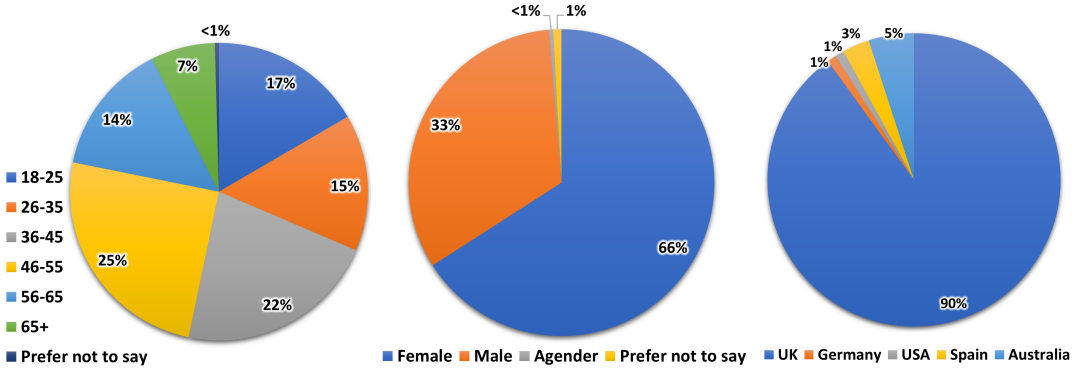
Schoettle and Sivak [15] performed a survey on people over the age of 18 to garner information on the public opinion of autonomous vehicles, with participants being from the USA, UK and Australia. Data of the general sentiment was collected and compared based on the country of origin of the participants. Several more focused questions were also asked to gain specific knowledge about the perception of issues such as traffic congestion, fuel economy and car accidents [15]. Overall, a positive sentiment was shown towards AV in each country, with Australia achieves the highest result of 61.9% of the participants stating that they had a positive opinion of AV, compared to the US that showed the greatest negative sentiment of 16.4%, compared to 56.3% having a positive sentiment of the people from the US that were surveyed.

In the work of Schoettle and Sivak [15], the respondents were asked whether they would want to own an entirely self-driving vehicle, with significant variations in responses being seen depending on the country the respondent was from. 67.7% in Australia were interested, with the US having 66.3% and the UK has 63.4%. However, the majority of respondents (34.2% average) were not interested in owning an entirely autonomous vehicle showing that there is still some lack of public interest or trust in self-driving vehicle solutions. This perception could have changed significantly since 2014, as in recent years there have been significant fully-autonomous vehicle solutions presented in the commercial space [5, 20] giving the technology more publicity and potentially altering public opinions.

There are several notable correlations between different responses in [15]. Higher levels of education resulted in a perception of autonomous vehicles bringing fewer car accidents, fewer severe accidents and less congestion. However, those with lower levels of education were less likely to ride in an autonomous vehicle, and would not perform other tasks whilst riding in the vehicle. It shows their distrust in the reliability and safety of autonomous vehicle solutions. Another observation was that those who had previous knowledge of AV were more aware of the potential benefits such as better fuel economy and a lower rate of accidents. Furthermore, those with prior knowledge were also more likely to want autonomous vehicle technology embedded in their vehicles, collating a greater understanding of AV with a desire to utilize the technology.

Public perception can vary depending on several main factors, including age and education [15, 27]. In the work in [27], a small sample of survey responses, from 107 people, were collected from Berkeley, California, where the survey asked respondents their opinions of AV. One key point to be taken from the results of this survey is that when asked about how AV should be integrated with normal traffic, 46% thought that AV should operate with normal traffic. The small sample size in a concentrated area is detrimental to gleaning meaningful information from these results, with opinions on the implementation of autonomous cars varying depending on the country as shown in the work of Schoettle and Sivak [15] who surveyed people from three countries. The survey conducted for this report takes this even further and has a wide variety of respondents from varying age groups and cultures.

There are also some prominent concerns that the public has with AV, such as system failure, interaction with non-AV and affordability [22]. Power [28] conducted a survey of premium vehicle owners, which found that 25% of male respondents were the most interested in fully AV at their current market price, with females showing more concern with regards to the pricing. There are several key factors considered for the costing of AV, as discussed by Wadud [29] who states that the size of the vehicle, the running costs for fuel, be it



(a) Age group (b) Gender (c) Countries

Fig. 1: Distribution of respondents in various age group, their gender and country of living

electrically powered or an Internal Combustion Engine, and maintenance as well as the initial investment in the vehicle are all prominent factors to be considered.

Several previous surveys have reviewed the public's acceptance of fully autonomous driving compared to partial autonomy, for instance, Power [28] found that the younger age groups had a more favourable opinion towards full autonomy, with 37% of 18-25 year-old respondents stating they would purchase a fully autonomous vehicle. Abraham et al. [6] asked respondents in their survey the preferred method of automation. A help driver was the most popular option for all age groups, with 56% of 65-74 year-old responding this way. Full automation was the preferred method for 40% of 25-34 year-old, showing a far higher result than that of Power [28] where 29% of 26-37 year-old stated they would purchase a fully autonomous vehicle. However, this lower result could be due to the investment of purchasing, rather than asking about a preferred option.

Abraham et al. [6] performed a survey to analyze the public preferences concerning autonomous vehicle technology, with participants being aged 16 and over. Basic information on age, gender and whether the participant owned a car were first asked before proceeding to the rest of the survey, which aimed to gain information on their preferences with regards to AV. The satisfaction level of the participants with the technology in their current vehicle was assessed, with 72% of respondents liking at least most of the features in their current car, showing a general satisfaction with current car technologies.

From the results of the survey conducted in [6], a matrix was constructed denoting the preferred learning method for in-car technologies depending on the age of the respondent. Some notable trends in these results were that younger people tended to use trial and error more to work out how to operate the technology, with a friend or family member demonstrating the technology also being a popular option. Older people preferred to use the vehicle's manual or other manufacturer created material, utilizing established and well-documented methods over trial and error approaches. Another question of note in the survey is regarding the age of the respondent and the approach to vehicular automation that is preferred. The five options to choose from were no automation, emergency only, having a help driver, partial autonomy and full autonomy. A help driver was by far the most popular with older age groups, with 56% of 65-74 year-old and 52.2% of over 75 states that a help driver was the preferable option for automating their vehicle. In contrast, those from ages 16-44 preferred the full automation approach with 40% of 25-34 years stating that full autonomy was their preferred option. Few of each age group chose no automation or emergency only, with most opting for at least a help driver as a form of automation in their vehicle.

When considering AV as an alternative to traditional transport, the public's sentiment of alternative transport methods should also be analyzed. In [6], the respondents were asked what methods of public transport they have used in the past instead of a car. The majority (67.7%) had used the subway, with the second-highest proportion (47.0%) having used the bus. However, when asked what their preferred alternatives to driving would be, 39.5% stated that car-sharing would be preferable, with 31.7% wanting to travel by electric bike. As personal methods of transport, such as cars, are preferred then AV could potentially gain acceptance in society due to the ease of transport and ability to travel to custom destinations, rather than relying on a set bus or train routes.

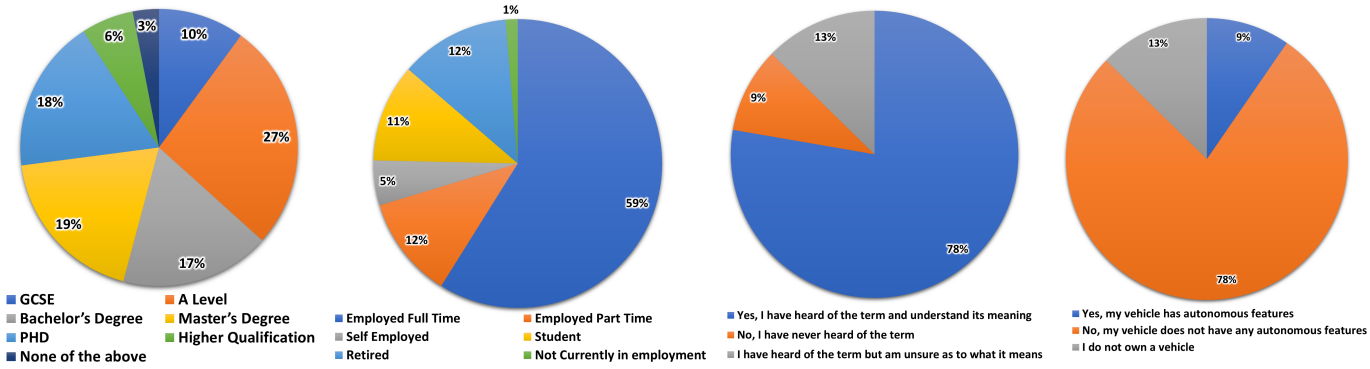
Bansal et al. [22] performed a survey reviewing the public's opinion of new vehicle technologies, where they surveyed 347 people. There were several key concerns highlighted by these respondents, with 50% being concerned about system failure, 48% with the potential issues with interacting with non-AV, and 38% of respondents were concerned with the affordability of the technology. Overall, the number of respondents who were concerned about learning to use AV was low at 7%, lower than other surveys conducted in recent years [6, 15]. The concern of software failure or misuse is shared between the work in [22] as well as that of [15] and [14] with respondents to the questionnaires evidencing a lack of trust in the software controlling the vehicle rather than having some form of manual input.

The work of Kyriakidis, Happee and de Winter [14] had a larger sample size of respondents than in the work in [22]. The median result for asking what year AV would be commonplace on roads was 2030, the lowest option possible, showing optimism from respondents for the acceptance of AV by the public. However, in the work of Begg [30], 10% of respondents stated that they believed fully AV would be on roads by 2030, this being due to either a difference in the survey group or a significant opinion shift over the year between the work of Begg [30] and [14]. One point of note is that in 2015, the UK government announced a review of autonomous cars [31], potentially making the public aware of autonomous vehicle technology and its potential applications.

3.1 User Acceptance Models

When discussing user perception of a topic, user acceptance models are beneficial in mapping the level of acceptance from a surveyed group. Especially for upcoming developments such as AV, gauging acceptance of new technologies is vital to implementing them in a manner that is suitable for the userbase through a robust feedback mechanism.

An example of an acceptance model is shown in the work of Hewitt et al. [32], that being the Autonomous Vehicle Acceptance Model (AVAM). This model is focused on the attitude and perceived safety of the users, providing topics such as these as an input to the user behaviour of the survey participants. In the survey, similar topics are covered to review the attitude of the public to the usage of AV with these topics being shown in the questionnaire structure in later sections. However, a difference can be observed in this model as there is an extra input of 'facilitating conditions' to the model. This is an independent input that is not normalized, unlike the other inputs



(a) Qualification (b) Employment status (c) "Autonomous Cars" awareness (d) Autonomous features

Fig. 2: Respondents qualification, employment status, their awareness of "Autonomous Cars" and whether they have owned cars with autonomous features.

to the model which are normalized into 'Behavioural Intention'. The survey work conducted in this paper is focused on the public view of AV rather than the usage behaviours, meaning that having an extra input such as this would not impact the outputs from the survey.

Another acceptance model is demonstrated in the research conducted by Koul & Eydgahi [33]. This work takes the Technology Acceptance Model (TAM) and applies it in the context of autonomous vehicles. Age and driving experience are used for intention of use of AV in this study, as is the case for our work in this paper. The overall focus of the study conducted in [33] is on the perceived ease of use of AV. This is only a part of the proposed survey, which consider a holistic approach as evidenced in the methodology and evaluation sections. Whilst our work does not propose a model for acceptance, the structure of the survey conducted is in line with existing, and modern, surveys in the same area, reinforcing the validity of the work.

3.2 Summary

To summarize, previous surveys show a trend between age and education with the acceptance of AV. The respondents to each survey who were younger, as well as those who had attained higher levels of education, mostly reacted positively to autonomous vehicle developments as well as being more versed in the functionality of AV [15]. As for when AV will become more commonplace in society, respondents to the survey conducted in [14] stated that, as a median result, fully AV would be commonly seen in the UK by 2030. The results from these surveys will be compared to the results collected from the survey conducted as part of this report to create a conclusion on the change, if any, in public perception of AV, as well as their role in future society.

This survey stands out from other surveys discussed in this work as it is an up to date review of people's opinions. Therefore, the survey that has been conducted is representative of the changes to the public perception of AV over the last few years. Given the shift in the market in the last few years, public perception has had a notable change. With companies such as Tesla becoming more prevalent in the past few years, the public's awareness of the different levels of autonomous features on vehicles will have become more abundant. The later sections of this work will discuss the results of the survey that has been conducted, drawing comparisons between the results of this work and older works, allowing insights on how opinions have changed to be gleaned.

4 Methodology

To provide a comparison to existing surveys on the topic of autonomous cars, a survey was conducted to glean an insight into the opinion of people from a variety of backgrounds on the current and future usage of autonomous cars in modern society. Several options were available for collating the opinions in question, with qualitative methods being favoured due to their ability to gain more detail on a given question through gleaning information about people's experiences [34]. A mixture of quantitative and qualitative methods allows for more varied insights to be gained from the results. For the purposes of this survey, a questionnaire was used due to the wide variety of responses required, and the number of people involved preventing methods such as a focus group being used. The strength of questionnaires lies in gaining in-depth opinions through interactions between several participants, having been used in previous research on the perception of AV by the public [35].

4.1 Survey Instructions and Questionnaire Content

A 46-item questionnaire is created using Google Forms. In the beginning, instructions to the respondents were provided including their participation is voluntary, their answer would be anonymous, the purpose of the study and its outcomes, contact information for further information and the survey would take around 10 minutes. The instructions provided also give high-level information about AV and a typical usage scenario.

The first four questions are to ask respondents whether they had read and understood the questionnaire instructions and their consent to take part in this survey voluntarily, and are free to withdraw at any time. The next set of questions are focused on their age, gender, education level and employment status to gain an insight into the sociodemographic background of each participant allowing for a correlation to be formed between the sociodemographic attributes and the perception of AV. Afterwards, a set of questions are aimed at the respondents' familiarity with the terms such as "Autonomous Vehicles", "Autonomous Technology" and "Self-driving Cars" to gauge the level of their prior knowledge before they gave their responses. The following 14 questions are focused on respondents feeling about the benefits of AV relating to transport-related and domain-specific attributes. A scoring system of very likely to very unlikely (5-point Likert scale where 1 = 'Very Likely', 2 = 'Likely', 3 = 'No Change', 4 = 'Unlikely' and 5= 'Very Unlikely') was used to provide quantitative feedback on a variety of questions related to the future implementation of AV. Then the next set of questions are on respondents concerns with AV-specific functionality, safety, hacking and liability with insurance providers. For this, participants are asked to register their concerns using a 3-point Likert scale where 1 = 'Not At All Concerned', 2 = 'Slightly Concerned' and 3 = 'Very Concerned'. Finally, the participants were asked whether they planned to purchase a vehicle with autonomous features as well as how many years in the future they would purchase it if they responded with maybe or yes. These responses can be correlated to the answers to the questions about the concerns with AV to gain an insight into the decision for wanting to purchase a vehicle with autonomous features; furthermore, the issues that those who would purchase an autonomous vehicle foresee can be highlighted.

4.2 Justification

The survey focuses primarily on the use of quantitative data. The two overarching questions posed to the participants where 'What benefits do you see' and 'What concerns do you have'. These questions could be answered using qualitative data where participants write about their opinions on AV. However, these responses would be difficult to model as participants may only provide a small amount of information, resulting in fewer usable insights. Instead, participants are asked about their opinions on specific benefits or concerns. This ensures that a consistent amount of data is collected per participant while still getting their opinions on the perceived severity of several points.

With regards to the approach taken in the grouping, the categories used for the user demographics such as age, gender and education level were modelled, and is based on similar studies in the field [32, 35]. The differences between the perception of AV by different age groups is discussed in the evaluation and results section, validating separation by age groups through providing evidence of results from the conducted questionnaire. Another notable category is ownership of AV, as participants are asked whether they own a vehicle which has AV features. By doing this, it allows us to justify their views accordingly. For example, those who own a vehicle with AV features have different biases to those who do not own a vehicle with AV features, and subsequently to those who do not own a vehicle at all. These three distinct categories are beneficial in separating users into demographics that will accurately show their varied opinions on AV based on their background. Further to this, prior knowledge of AV was also assessed, as those with greater knowledge and understanding of AV could have a greater appreciation for AV, causing their responses to be substantially different to those of someone who had no prior knowledge of what an AV is.

4.3 Participants

There is no specific target group for the questionnaire, the survey being distributed over social networking websites and online automotive groups. The data collection began in January 2018 and analysis took place in April 2018. During this period, a total of 229 surveys are considered with respondents aged 18 and over. Of this sample, 65.9% are female and 32.8% are male, with 0.4% agender (opportunity to state 'other') and 0.9% are selected 'prefer not to say' (see Fig. 1b). This study consists of significant female respondents in comparison to the existing studies [10, 14, 15, 27]. Respondents came from four major countries (see Fig. 1c), which are the UK (90%), Spain (3%), US (1%) and Australia (5%) with not all respondents owning a vehicle. The respondents' age is ranged from 18 to 65+ years and is grouped into 18 – 25 (16.6%), 26 – 35 (14.8%), 36 – 45 (21.8%), 46 – 55 (24.9%), 56 – 65 (14.4%) and 65+ (7%) years (Fig. 1a). We have also provided the option of 'prefer not to say' (0.4%). The education level of the participants is captured (see Fig. 2a) using the following attributes: 1) GCSE/high school (10%), 2) A-level/higher secondary (26.6%), 3) Higher qualifications (6.1%)(e.g. diploma, higher apprenticeship, higher national certificate, foundation degree, higher national diploma, etc.), 4) Bachelor degree (17.5%), 5) Master degree (18.8%) and 6) PhD (17.9%). We have also given the option of 'None of the above' (3.1%). In our survey, more than 63% of respondents have a higher qualification of bachelor degree or higher and is different from the existing studies [15, 27]. In total, 78% of respondents do not own a vehicle with AV features, 5% have AV features, and 13% do not own any type of vehicle.

The respondents' current employment status (Fig. 2b) is recorded using six attributes: 1) Employed full time (59.3%), 2) employed part time (11.9%), 3) self employed (4.8%), 4) students (10.5%), 5) retired (11.7%) and 6) not currently in employment (1.3%). The survey is also involved a question about the awareness of the term "Autonomous Cars" to the respondents in which 77.7% of the respondents have heard the term and understand its meaning and 9.6% have never heard the term whereas, the rest 12.7% have heard the term but unsure what it means (see Fig. 2c). In order to associate the familiarity of this term with the respondents' own vehicle, we also asked the following question "Do you currently own a vehicle with autonomous features?" (Fig. 2d). Majority of the respondents (77.7%) have answered 'no' which is similar to the question on the awareness of the term autonomous cars. This implies respondents do not have a vehicle with autonomous features, but they are conscious of the term autonomous cars.

4.4 Constraints & Limitations

Due to the nature of using questionnaires, the collected data is limited by the people being surveyed. For this work, one of the main constraints is the limited variety in countries for the respondents. As shown in Fig. 1c, 90% of the respondents are from the United Kingdom, meaning that the constraint is that the perception could be skewed depending on the usage rate of AV in the UK at the time of being surveyed. For other major countries surveyed, 3% are from Spain and 5% from Australia, giving some variety to the responses.

Another constraint in representation is that the respondents are 66% female, with 33% being male, as evidenced in Fig. 1b. Whilst this might not cause bias, it does limit the representation of one gender. However, the age groups surveyed are relatively balanced, with only 65+ being the outlier with 7% of respondents being in this group. Therefore, this should not be considered a constraint of drawing conclusions from the survey data.

A constraint that should be considered is the usage of autonomous vehicles, as only 5% of people own AV with autonomous features (see Fig. 2d). This could constrain the knowledge of the respondents about AV, although they could have been in or used AV in the past that they did not own. This is reflected in the data on understanding of AV, as 78% of those surveyed stated that they have an understanding of the term 'Autonomous Vehicles'. However, given the remainder who did not have an understanding, this results in limiting the validity of responses from participants.

4.5 Validity & Reliability

In contrast to the existing studies, our study has gathered responses from people with diverse qualifications and education levels, providing a varied view of the perceptions of different backgrounds of the public on AV. Varied responses promote validity of the study, as the responses are less subject to bias. Furthermore, given the high awareness of what AV are, 78% of the participants (see Fig. 2c) has a high knowledge of the AV subject. This will allow them to give more informed responses to the questions proposed regarding the risks and acceptance of AV.

Table 1 Respondents demographic profile of age against highest education level. This table shows how the highest level of education achieved by a participant affects their views on AV.

	18-25	26-35	36-45	46-55	56-65	65+
GCSE	1	0	5	12	2	2
A-level	16	1	3	7	8	5
Bachelor's Degree	16	8	13	12	6	6
Master's Degree	4	11	10	14	3	1
PhD	0	11	14	6	10	0
Higher Qualification	1	2	5	4	1	1
None of the above	0	1	0	2	3	1

Table 2 Respondents demographic profile of age against ownership of vehicles with AV features. This shows how age affects the perception on usage of AV, and whether certain age groups are more in favor of using AV.

	18-25	26-35	36-45	46-55	56-65	65+
Has AV features	2	2	8	4	6	0
Does not have AV features	19	28	40	49	27	14
I do not own a vehicle	17	4	2	4	0	2

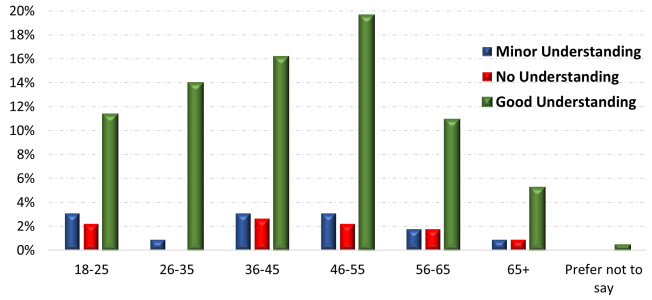


Fig. 3: Comparison of age groups and their prior knowledge of the existence of autonomous vehicles.

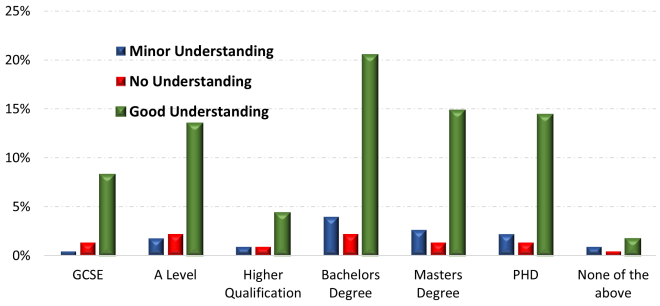


Fig. 4: Comparison of education level and prior knowledge of autonomous vehicles.

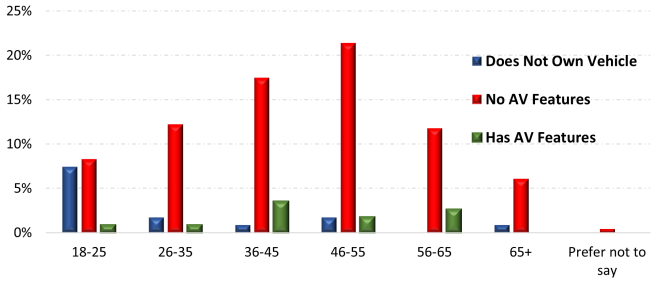


Fig. 5: Comparison of age groups and their usage of autonomous vehicle technology.

Alongside these points, there is a wide age range that has been surveyed. As stated in the constraints and limitations section, there is a balanced amount from each age group aside from 65+ (7% of respondents). With the different levels of education and the variety of age groups, both of these together provide a strong foundation for a valid variety of responses.

For the questions posed in the questionnaire, the key sections of benefits and concerns cover 30 questions (15 each) to give a varied set of questions for respondents to answer. This means that even if respondents are unsure on one question, then the responses from other questions can be used to glean useful insights into their perception of AV given the specified question. Combining the demographics with the different sets of questions, the work conducted in this study provides a varied, and therefore valid, set of responses on the public perception of AV in modern society. The reliability of this study can be attested as well since there were multiple categories to reinforce the trends in opinions linking each demographic question.

5 Questionnaire Survey and Evaluation

The questionnaire was completed by 229 people, of which 70 gave additional comments pertaining to the study itself or potential amendments that could be made, should the questionnaire be given out again. The main points of comparison for reviewing the concerns with AV are the age and level of education of the respondents, as in previous studies [6, 15] these were the two factors that were highlighted as heavily influencing the respondent's perception of AV.

The initial question of the participant's prior knowledge of AV can be compared to the age group of the participant (see Fig. 3). As shown in the figure, the age group of 46-55 had the lowest proportion of respondents who did not understand what is meant by the term "autonomous vehicle". For the younger age groups, there was a larger proportion who did not understand the term but still had a substantial number who did, 18-25 years having 11.4% respondents who understood the term "autonomous vehicles" compared to 14% 26-35 year-old. One point of note is that the 26-35 age range is the only subset that did not have any respondent who had never heard of the term "autonomous vehicle".

The highest level of education of the respondents can be compared to their prior knowledge of autonomous vehicle technology. There is a notable trend of respondents who have attained a higher level of education is more likely to understand what is meant by "autonomous vehicles" (see Fig. 4). This is notable in those who had A-level or GCSE qualifications only where there were more people who had never heard of the term than those who had heard of it but were unsure of its meaning. When reviewing the age groups and their usage of autonomous technology, there was no clear trend shown; notably in the younger age groups, where many of the 18-25 age group did not own a vehicle. Fig. 5 depicts the participants and whether they own a vehicle with autonomous technology, showing the results from respondents who both owned and did not own a car unlike the survey conducted by Abraham et al. [6], where the respondents who did not own a car were screened out at the first few questions of their questionnaire. However, this does allow for a broader range of views to be obtained on AV as those who do not drive could have a different view of the impact of AV. The highest level of education of the respondents can be compared to their prior knowledge of autonomous vehicle technology. There is a notable trend of respondents who have attained a higher level of education being more likely to understand what is meant by "autonomous vehicles" (see Fig. 4). This is notable in those who had A-level or GCSE qualifications only where there were more people who had never heard of the term than those who had heard of it but were unsure of its meaning. Table 3 shows a matrix of the results for whether the respondents thought that autonomous cars would reduce the number of car crashes. The percentage of each age group that selected each option is shown to evidence the distribution of each group. Most respondents of each age group stated that they believed it is likely that AV will reduce the amount of car crashes, with the 36-45 age group having the highest percentage who believed this. However, there were a substantial number of the 36 and above age groups who thought that there would be no change from current vehicles in reducing the number of accidents by using autonomous technology, with the 26-35 age group having the lowest percentage of its distribution that believed this. This is due to the 26-35 age group having 20.59% of respondents state that they believe it is unlikely that autonomous cars will reduce the number of car crashes. Overall, the majority of respondents stated that they believed autonomous cars would reduce the number of car crashes.

Several key concerns of the public were identified through reviewing previous works [15], with these concerns being used to construct the large remainder of questions for the survey. Respondents were asked what benefits AV could bring, and what the potential issues

Table 3 Respondents opinion on the use of AV in reducing crashes

	18-25 (%)	26-35 (%)	36-45 (%)	56-65 (%)	65+ (%)
Very Likely	18.42	32.35	8.00	12.12	6.25
Likely	47.37	35.29	54.00	45.45	56.25
No Change	18.42	5.88	16.00	21.21	18.75
Unlikely	13.16	20.59	18.00	9.09	12.50
Very Unlikely	2.63	2.94	2.00	9.09	6.25
Do Not Know	0.00	2.94	2.00	3.03	0.00

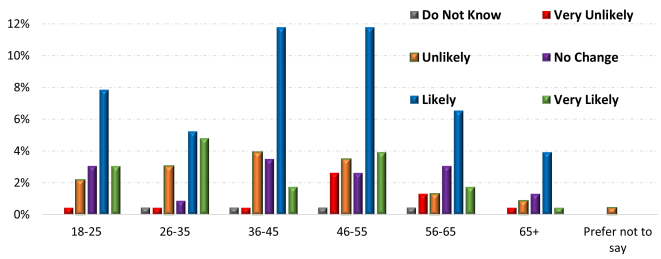


Fig. 6: Autonomous vehicles reducing the number of car crashes (age group).

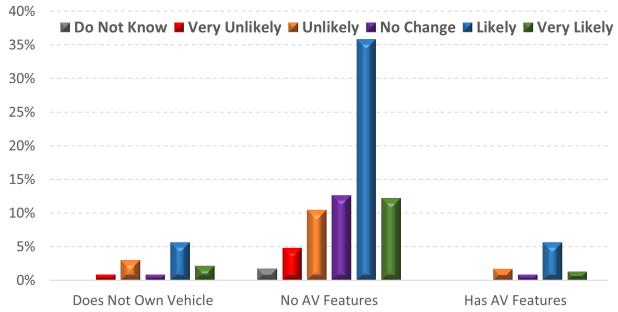


Fig. 7: Autonomous vehicles reducing the number of car crashes (ownership of AV).

could be. Each question was given a scoring scale of 'very unlikely' to 'very likely' to gauge the respondent's thoughts on the future position of AV in society. The following analysis and various plots depict the distribution of results for most of these questions.

Throughout all age groups, a clear trend can be seen of the majority of respondents believing that AV would reduce the number of car crashes, a trend also shared in the work of Schoettle and Sivak [15] where an average of 45.8% of respondents from three countries believed that there would be fewer crashes were AV to replace traditional vehicles. One notable trend in Fig. 6 is that the higher age groups, aside from 36-45, had a far higher percentage of people responding with likely rather than very likely. Furthermore, the older the respondents were the more they stated it is likely that AV would not reduce the number of crashes, with the 46-55 age group having the highest number of very implausible responses and the second highest number of unlikely responses (3.5% compared to 3.9% for the 36-45 age group).

Respondents were also asked about whether AV would create new jobs in the automotive industry (see Fig 8). All age groups, aside from 36-45 and 65+ had the majority of respondents state there would be no change in the number of jobs. Whilst most age groups did not believe it very unlikely or very likely for new jobs to be created through AV, there is a relatively even distribution between unlikely, no change and likely responses for most age groups - notably for the 18-25 age group, resulting in no clear correlation overall. Fig. 9 compares respondents results based on education level rather than age. The participants were also asked about their concerns with AV, with the cost of the new technology being a core issue. Fig. 11 shows the level of concern of the respondents with the cost of AV, sorted by age group. Overall, half of the age groups had a majority response of slightly concerned, with the rest having not concerned as the majority. However, the 18-25 and 56-65 age groups have a notable spike in respondents being slightly concerned with the cost of AV. Fig. 13 shows how concerned respondents were with learning to use AV related to their age group. Higher age groups showed more concern with learning to use the vehicles, notably in the 46-55 and 56-65 age groups. In contrast, the 26-35 age group has a far larger proportion of respondents who are not concerned with learning to use the autonomous features with 36-45 years old are sharing

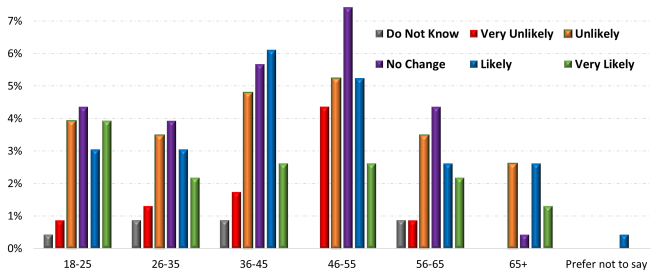


Fig. 8: Autonomous vehicles technology creating new jobs (age group).

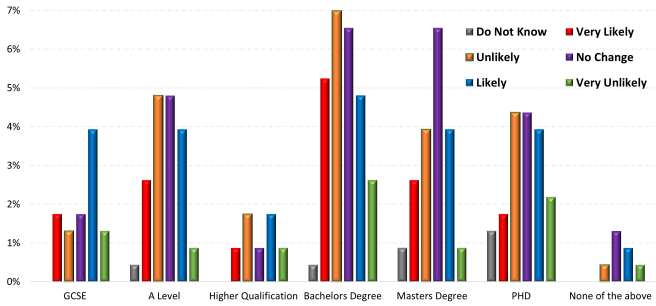


Fig. 9: Autonomous vehicles technology creating new jobs (education level).

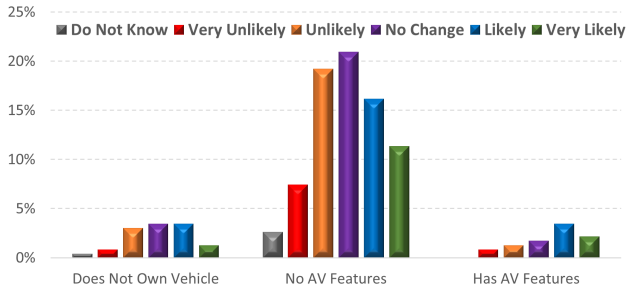


Fig. 10: Autonomous Vehicles technology creating new jobs (ownership of AV).

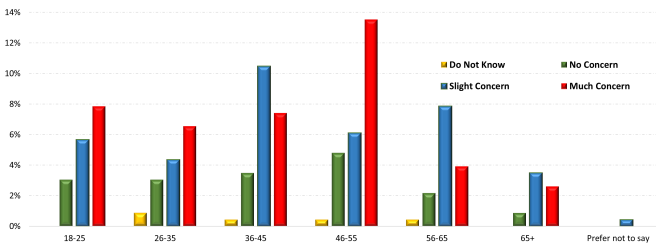


Fig. 11: Concerns with cost of autonomous vehicles (age groups).

the same trend. Abraham et al. [6] reviewed the preferred methods of learning to use technology in cars, as well as the preferred methods of learning. A notable trend from the data they collected was that trial and error had a large proportion of people who used it in the past but would not prefer to use it. Around 39% stated that they would prefer the car teaches them, and 59% would prefer to be taught by the vehicle's manual. The older age groups preferred to learn through manuals and manufacturer material, whereas younger age groups preferred to learn through trial and error or through the car itself teaching them. When applied to the results in Fig. 13, the respondents of the older age groups could be more concerned as they worry

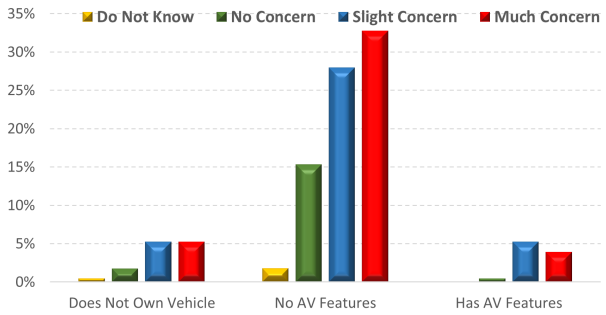


Fig. 12: Concerns with potential cost of AV (ownership of AV).

that the vehicle's manual or manufacturer-provided material will not be sufficient to explain the complexities of the autonomous features. After questioning respondents on their main thoughts and concerns

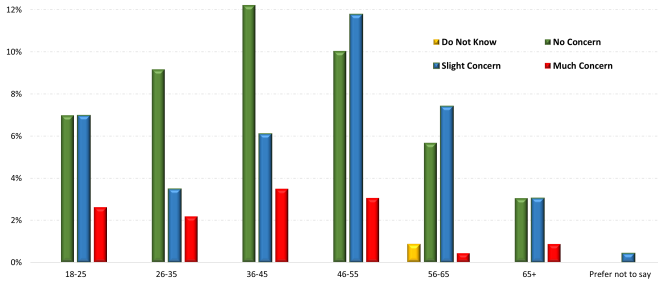


Fig. 13: Concerns with learning to use autonomous vehicles.

with autonomous vehicle technology, they were then asked about whether they would consider purchasing a vehicle with autonomous features and, if so, at what point in the future. Figures 14 and 15 show the results for if the respondent would purchase a vehicle with autonomous features, based on age group, as well as when they would like to purchase the said vehicle. Most respondents were positive about the impact of AV overall, with notable trends showing that age group and education level have some impact on the respondent's choices. Cost (see Fig 13) was the main concern for autonomous vehicle technology due to its complexity and potentially high manufacturing costs [8]. Overall, 43.7% of the respondents stated that they would potentially buy an autonomous car, with the remainder stating they already own a vehicle with autonomous features (6.1%), or that they would not buy a vehicle with autonomous features.

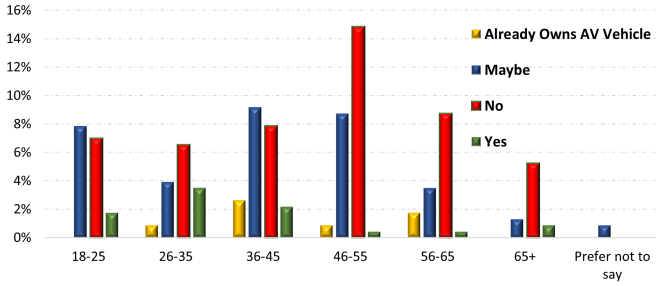


Fig. 14: Whether the respondents would purchase a vehicle with autonomous features by age group.

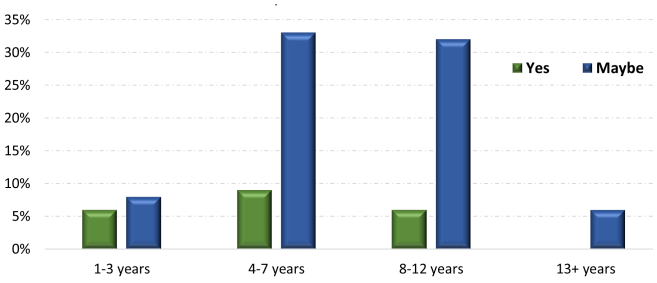


Fig. 15: Respondents who would like to purchase a car with majority of autonomous features in the near future.

6 Results and Discussion

The questionnaire in this study can be grouped into four main categories: 1) public awareness of AV, 2) public concerns of AV, 3) public perception on benefits of AV, and 4) public acceptance of AV. In this section, the results involving respondents' responses are analyzed and discussed.

6.1 Public Awareness of Autonomous Vehicles

The results of this survey found that a total of 91% of participants had heard the term "autonomous vehicle" before or even had a strong understanding of the term (see Fig. 2c). This shows a huge increase to previous studies that found only 66% of participants had heard the term before in 2014 [15] and 87% in 2016 [21]. This indicates a rapidly increasing awareness of autonomous technologies to the public. Schoettle & Sivak [15] states this is due to the increasing coverage by the media on self-driving vehicles by large companies such as Google and Tesla. This coverage is allowing more of the public around the world to become more informed of the topic and comprehend where the future of driving is heading. Although experts are predicting high-level AV to only be commercially available in over a decade [36], low to mid-level autonomy is to be widely used well before that as major manufacturers are already implementing such technology. As such, it is important for the general public to be aware of what these modern cars are capable of or aiming to achieve.

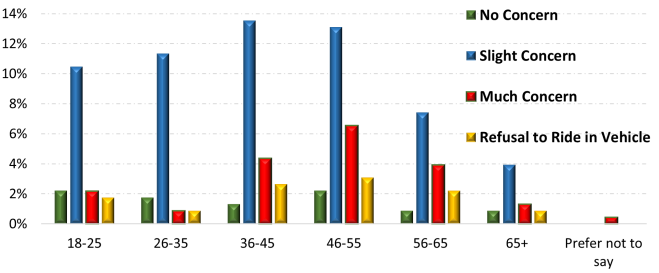


Fig. 16: Concern of respondents about riding in or driving a car with autonomous technology

6.2 Public Concerns of Autonomous Vehicles

Public concerns on the rise of the AV are captured by 16 questions, as shown in Fig 17. These questions are: 1) vehicles not driving as well as humans, 2) vehicle performance in unexpected situations, 3) vehicle performance in poor weather, 4) learning to use the vehicles, 5) interaction with pedestrians, 6) interaction with non-autonomous vehicles, 7) safety consequences, 8) vehicle hacking, 9) riding in a vehicle with no driver controls (e.g. steering wheel, brake pedal etc.), 10) recognition of road signs and markings, 11) liability for incidents, 12) the price of purchasing an AV, 13) the cost of running the vehicle, 14) loss of jobs from the technology, 15) insuring the

vehicle, and 16) system crashing or malfunctioning. The responses to these questions are captured using a 3-point Likert scale ('very concerned', 'slightly concerned' and 'not at all concerned'). There is also an option of 'do not know'. The responses are presented in Fig 17. The top-3 'very concerned' responses are to the questions: 16) system crashing or malfunctioning (56%), 9) riding in a vehicle with no driver controls (55%) and 2) vehicle performance in unexpected situations (52%). The system failure is also a prominent concern identified in [22]. We also further analyze the concern of system failure with respect to respondents' qualification (Fig. 20a), employment status (Fig. 20b), age (Fig. 20c) and owning cars with autonomous features (Fig. 20d). Overall, respondents with various sociodemographic characteristics are all 'very concerned' with system failure. However, the difference between 'very concerned' and 'slightly concerned' is minimal in respondents with a PhD degree (see Fig. 20a). A similar observation is seen in respondents with student status (see Fig. 20b). It could be due to the student and PhD degree holders are more familiar with the term AV. The respondents within the 26-35 age bracket (see Fig. 20c) are 'slightly concerned' (7.9%) in comparison to 'very concerned' (6.1%). This is clearly aligned with the previous observations in Fig. 3 in which respondents within this age bracket have a very good understanding of the AV.

The top-3 'not at all concerned' are (see Fig 17): 13) the cost of running the vehicle (36%), 15) insuring the vehicle (31%), and 14) loss of jobs from the technology (28%). We have also looked into the relationships between "liability for incidents" involving AV and respondents' qualification (Fig. 19b). It is clear that respondents with higher qualification (bachelor degree or higher) has more inclined towards 'slight concern' than 'much concern'. Whereas, people with school level qualifications are more inclined towards 'much concern'. This suggests that more awareness is required about the AV, its autonomous features and safety.

There are 70 respondents gave additional comments in the provided free-form comments box. The primary concern among them was the cost of these vehicles. This concern was particularly high from respondents in the 18-25 age bracket. Interestingly, although the majority of respondents in this bracket stated they are slightly concerned over the cost, far fewer people expressed any major concern when presented with the question (see Fig. 11). Howard and Dai [27] had similar findings across each of their demographics and suggests that more analysis on the public willingness to pay for autonomous features be done to investigate this concern. A minor concern that was shown is the potential of a steep learning curve of using AV. As they are not fully self-driving, the driver still has to control the vehicle; only receiving minor assistance in low-autonomy vehicles. This assistance is through small features such as cruise control and self-parking [37]. Although manufacturers attempt to make these systems user-friendly, this does not always occur, which can result in people being concerned about technology that they have little experience using. KPMG [8] acknowledges the need for these AV to facilitate the consumers learning of autonomous feature in order to improve the public's perception and acceptance of AV. Those in the younger age brackets primarily expressed no concern about learning such technology likely due to being more exposed to modern devices, giving them more confidence. The 18-25 bracket had an equal amount of those being not concerned at all and those who are slightly concerned. The reason for being slightly concerned could be attributed to those who are less familiar or experienced with driving in general rather than a concern learning just the assistive technology. More concern was shown by older respondents, showing more or equal amount of concerns versus those who are only slightly concerned. As the level of autonomy increases drivers should be less concerned with learning to use these systems as the vehicle will have more and more control over the car; giving the driver fewer responsibilities.

6.3 Public Perception on Benefits of Autonomous Vehicles

The benefits of AV are captured using 14 questions, which are: 1) fewer car crashes, 2) cheaper insurance rates, 3) reduced severity of car crashes, 4) reduced traffic congestion, 5) reduced travel time, 6) reduced emissions, 7) safer roads, 8) improved fuel efficiency, 9) passengers will have more free time, 10) simpler driving examination, 11) reduced chance of becoming lost, 12) creation of new jobs, 13) better transportation services, and 14) better health. The responses to these questions are captured using 7-point Likert scale ('very likely', 'likely', 'no change', 'unlikely', 'very unlikely', 'do not know') and is shown in Fig. 18. The majority of the respondents are given a response of 'very likely' or 'likely' except to the 14) better health (49%), 13) better transportation services (46%), 12) creation of new jobs (38%), 10) simpler driving examination (39%), 5) reduced travel time (34%), 4) reduced traffic congestion (39%), and 2) cheaper insurance rates (45%) questions. The respondents also think that 8) improved fuel efficiency (72%), 11) reduced chance of becoming lost (68%), fewer car crashes (63%), 6) reduced emissions (62%), and 3) reduced the severity of the crashes (62%) are the most beneficial of having AV. The most 'very unlikely' benefits are: 5) reduced travel time (11%), 4) reduced traffic congestion (10%), and 12) creation of new jobs (9%).

6.4 Public Acceptance of Autonomous Vehicles

There has been much research into the benefits of AV. One of the biggest being improved safety for both the driver and pedestrians. Penmetsa et al. [38] found that 62% of respondents believed that AV would reduce the rate of accidents and injuries and felt safer when cars with autonomous features were around. This lines up with what the respondents from this survey said (see Fig. 18). When asked about their opinion on AV reducing the number of accidents the overwhelming view across each bracket was that it was likely to be reduced. Although 'unlikely' was reasonably high in the younger brackets 'likely' and 'very likely' were still the more prevalent responses (see Fig. 6) indicating that they view AV having in a positive, safe impact on driving.

However, despite these findings, no age bracket in this survey expressed a strong interest in owning an AV (see Fig. 14). The majority answer for each age bracket was 'no' except for 18-25 and 36-45 which had a marginally higher response of 'maybe' but still a very high number of responses to 'no' compared to 'yes'. It is unclear as to each person's reasoning but the likely reason could be that there is a lack of incentive to make the purchase so early in the development of the technology. The majority of modern cars are only defined as level 2 autonomy, meaning vehicles will not be actually in control until level 4. At this point when cars can make decisions for the driver, it is likely people will be more inclined to make the switch rather than switching now and only getting basic assistance such as parking, collision avoidance, distance maintenance, etc.

7 Conclusion

To summarize, this work iterates on the previous studies on users acceptance of the autonomous vehicles and looks at the gaps in the knowledge on this topic. The study not only looked into the factors that play a role in people's acceptance, but also the implications of these factors for wider acceptance such as national government and the automotive industries, as well as the perceived role of autonomous vehicle technology in future society. This is to make sure to understand the potential benefits and concerns related to the introduction of AV and to ensure that technology becomes a success. The goal is to understand how the public will respond to such technology, and what possible benefits or difficulties they perceive at an early stage, preferably before the technology is publicly available. Factors found to play a role in people's acceptance is grouped into four categories; awareness of AV, benefits of AV, concerns with AV and acceptance of AV. Overall, our analysis revealed that the AV are perceived in a generally positive light and "somewhat low risk" to drive. The respondents are most concerned about crashing/malfunctioning, purchase price, liability for incidents, interaction with non-AV, performance in unexpected situations, hacking and safety. The results also revealed that gender, age, education level and employment status had varied relationships with

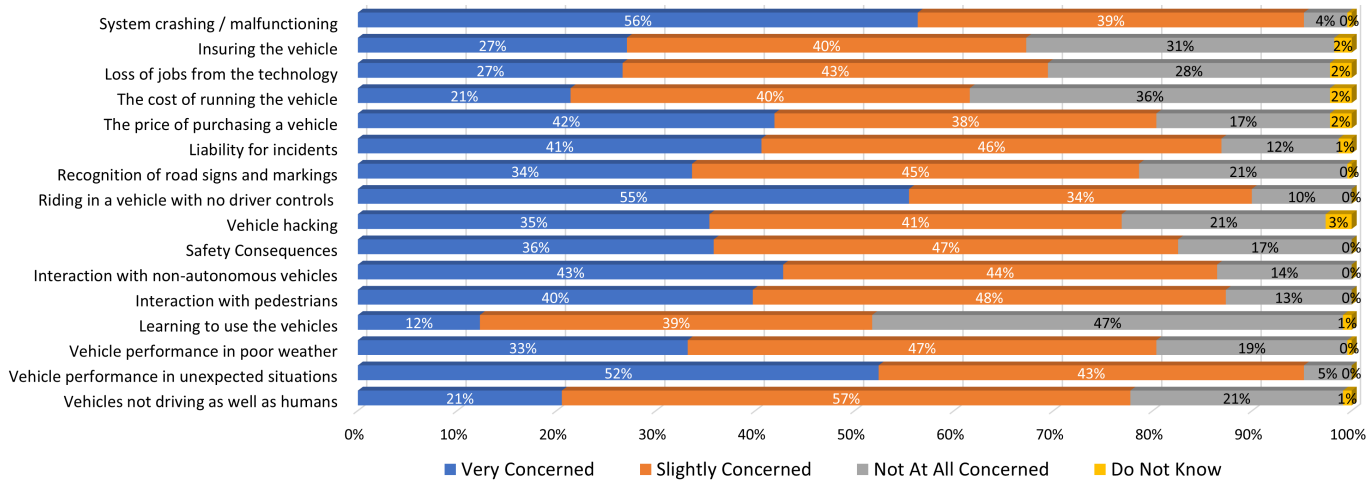


Fig. 17: Respondents responses to the questions linking their main concerns with the autonomous cars.

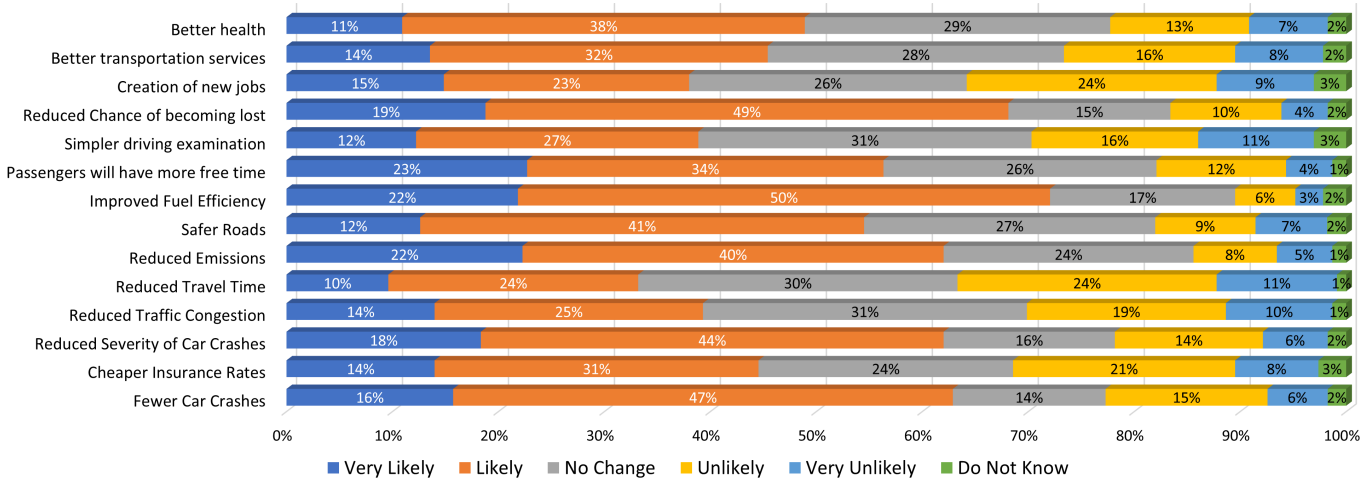


Fig. 18: Respondents responses to the questions linking benefits of autonomous cars.

the perceived concerns and general attitude towards AV. For instance, respondents with a university degree (bachelor/master/PhD) are less concerned about the liability of accidents and AV system failure than those without it. Similarly, respondents between 36 – 65 years of age are more concerned and even refused to drive AV in comparison to the age ranges of 18 – 35 years and 65+ years. This suggests AV are multi-faceted and will not be a case of automotive industries having to win over "the people" per se since this study clearly demonstrates that the people are not a single entity with respect to this new revolutionary form of transport. One of the key aspects of this study is that majority of the respondents are female (66%), and a significant number of them (37%) are holding a postgraduate-level (Master/PhD) qualification. Therefore, this study is significantly different from the existing ones [6, 10, 11, 13–15, 21, 22].

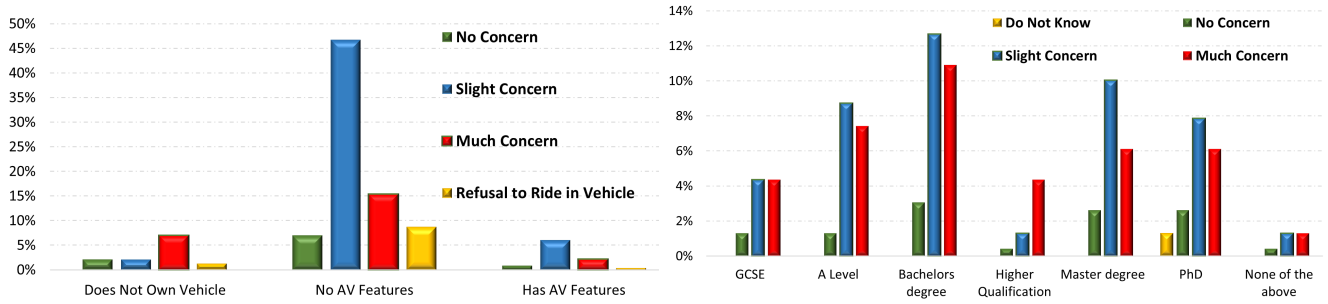
In future surveys and analysis, a muti-perspective approach should be adapted by the researchers and focus on trials with real interactions between users and AV. Furthermore, actual demonstration of AV, their safety performance and benefits should be demonstrated. This would overcome some of the concerns raised in this study such as AV's performance in poor weather conditions and unexpected environments, system malfunctioning and safety.

One of the key issues encountered with finding concrete trends in the data is that the sample size is small, notably when the results were split into groups based on age or highest level of education, meaning that potential trends might be distorted; for example, the number of respondents that stated they had obtained 'higher education' or had not received any form of education that conformed to the options given was small, meaning that even a few results for one option could have skewed the data by a large amount. However, for the groups that had a suitable number of respondents representing them, meaningful trends were noted in the perception of issues such as vehicle cost and the frequency of car crashes, allowing correlations to be formed from the data.

8 Future Works & Recommendations

This survey can be used in future research make comparisons between similar studies on public perception of AV from different key demographics such as age or country. These findings can also be compared to different years to plot the change in public perception of AV over time. As well as comparisons, the points and concerned raised by the participants can be used in the development and marketing of AV to identify and address concerns that people may have.

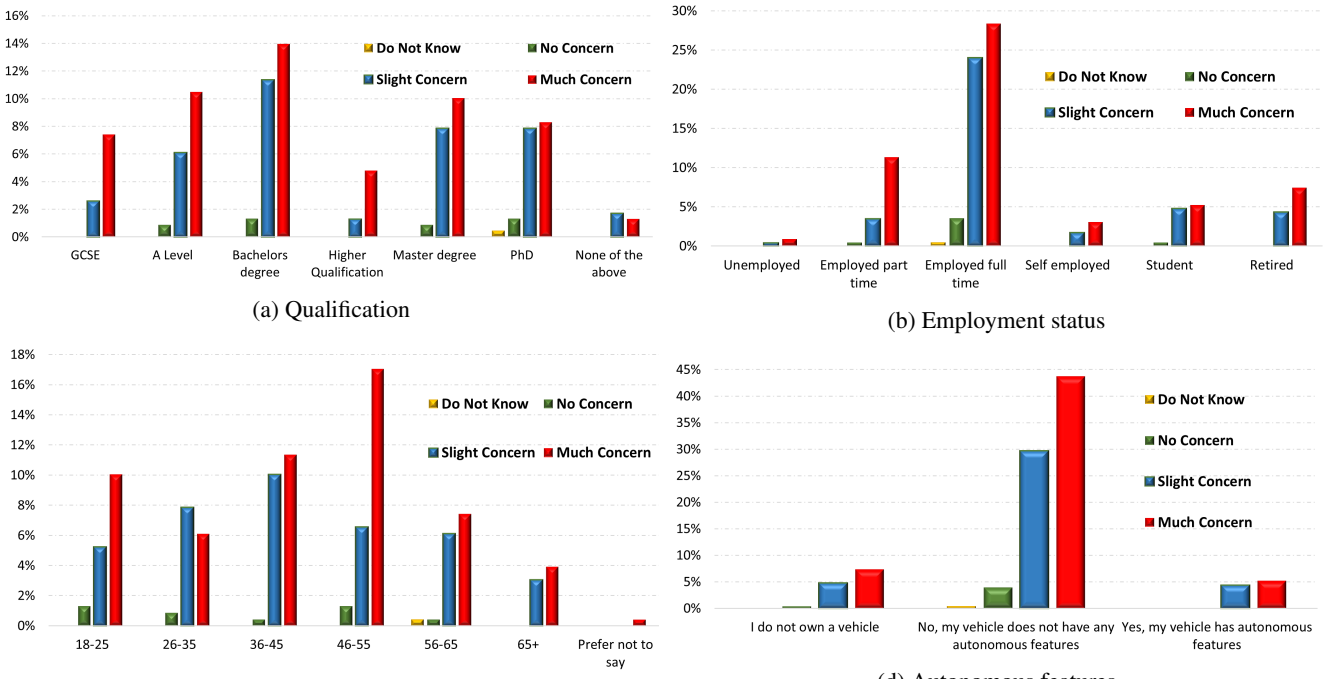
From this work, a recommendation can be given to monitor the trends in AV perception by the public. As evidenced by the discussions in the evaluation section of this work, there have been shifts in perception due to a raise in awareness of what AV are and how autonomous features are being implemented in modern vehicles. Furthermore, with regards to the perception of rate of accidents, the results from the survey conducted in this research are in-line with other recent works [38]. Given the rise of car manufacturers around the world adopting autonomous features in their vehicle lines, the public perception will change even more and more autonomous features are integrated into lower-cost vehicles. Therefore, this work recommends that future works analyze older surveys on the public



(a) Driving a car

(b) Liability for accident

Fig. 19: Ownership of vehicle with autonomous features and linking qualification with liability for accidents.



(a) Qualification

(b) Employment status

(c) Age

(d) Autonomous features

Fig. 20: Concern of respondents about system failure linking education level, employment status, age and owning cars with autonomous features.

view of AV, to gain a full picture of the shift in perception over time as AV became more mainstream in their usage.

9 Acknowledgements

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